Shelling

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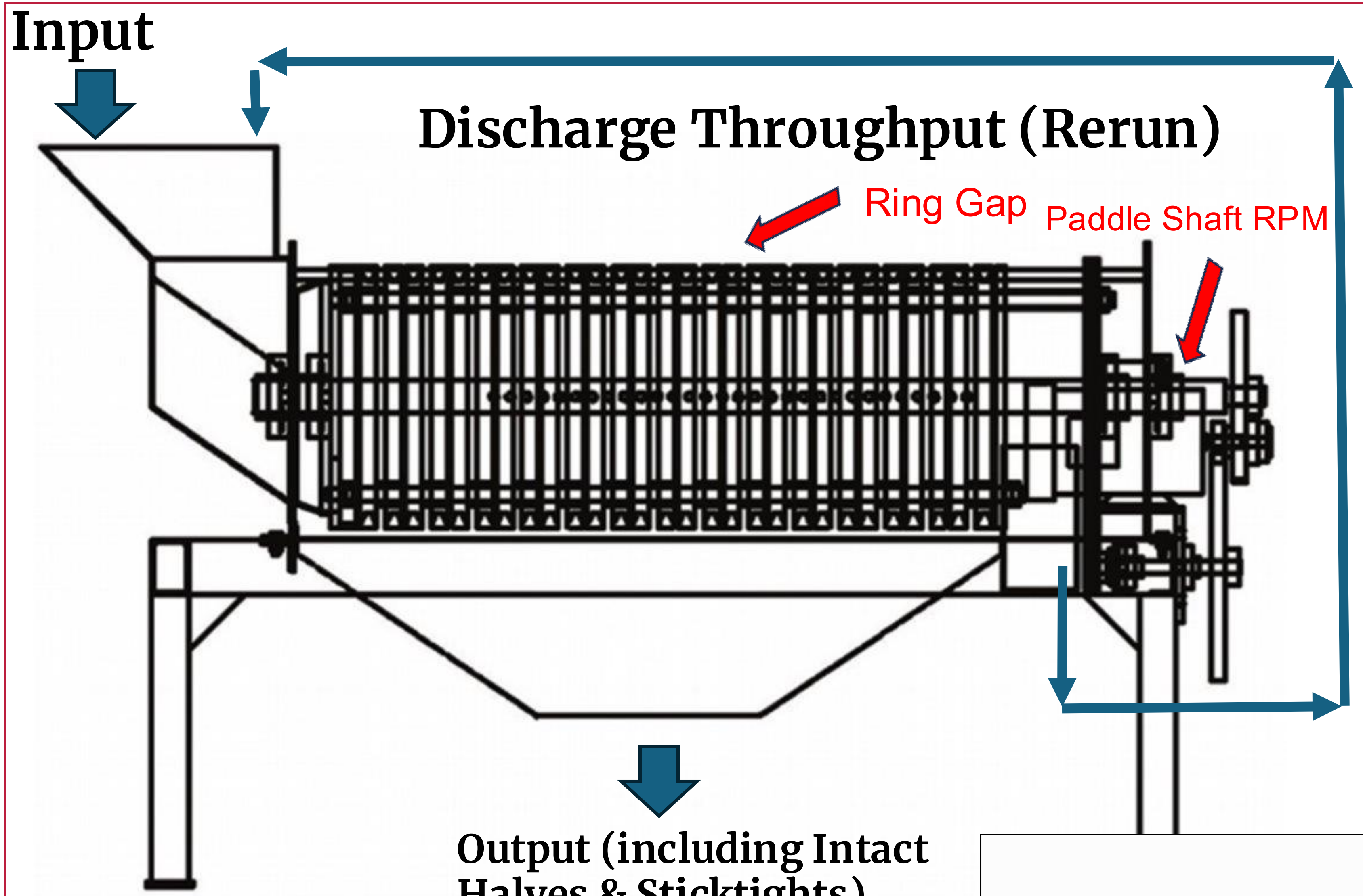
Agenda

- **Moisture Effects and Sheller Process Variables**
  - 2025 Recap & Motivations
  - Experimental setup & Analysis result
  - Recommendations.

- **Sheller Pin Study**
  - Experimental procedure & 2025 Recap
  - Pin configurations
  - Observations and analysis
  - Interaction of sheller parameters & pin configurations

Discharge Throughput (Rerun)



Output (including Intact Halves & Sticktights)

Dependent Variables
Intact Halves
Discharge Throughput
Sticktights
Processing Time

$$\text{Discharge Throughput (\%)} = \frac{\text{Total Discharge}}{\text{Sheller Input}} \times 100$$

Moisture Effects and Sheller Process Variables

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2025 Recap & Motivations

2025 Workshop	2025-2026 Experiments
Single effect of moisture & sheller parameters on dependent variables	**Interaction effect** of moisture & sheller parameters on dependent variables; with more comprehensive testing.

- **Motivations:**
  - **Limited understanding** of moisture–sheller parameters interactions
  - Moisture interact with sheller parameters **affects significantly and further** on response variables.
  - Identify clear interaction relationships promote **data-driven process optimization.**

Experimental Setup

- **Conditioning Method:** Cold-bath conditioning. (Table 1).
- **Experimental Design:** Three moisture level, 27 trials per level (Tables 1 & 2).
- **Research Sheller parameters:** **Ring Gap, Paddle Shaft RPM, Moisture Category**
- **Research Objectives:** **Intact Halves, Discharge Throughput**

Table 1

Moisture content with soaking hours

Soaking Time Window (Hours)	Targeted Moisture Content (%)
06–07	5
15–20	7
27–30	8–9

Table 2

Experimental variables for a 14" Pecan sheller

Independent Variables	Level 1	Level 2	Level 3
Ring Gap (inch)	+0.0	+1/16	+1/8
Paddle Shaft Velocity (RPM)	400	600	800
Drum Velocity (RPM)	25	30	35
Moisture (%)	5	7	8–9

Analysis – Intact Halves

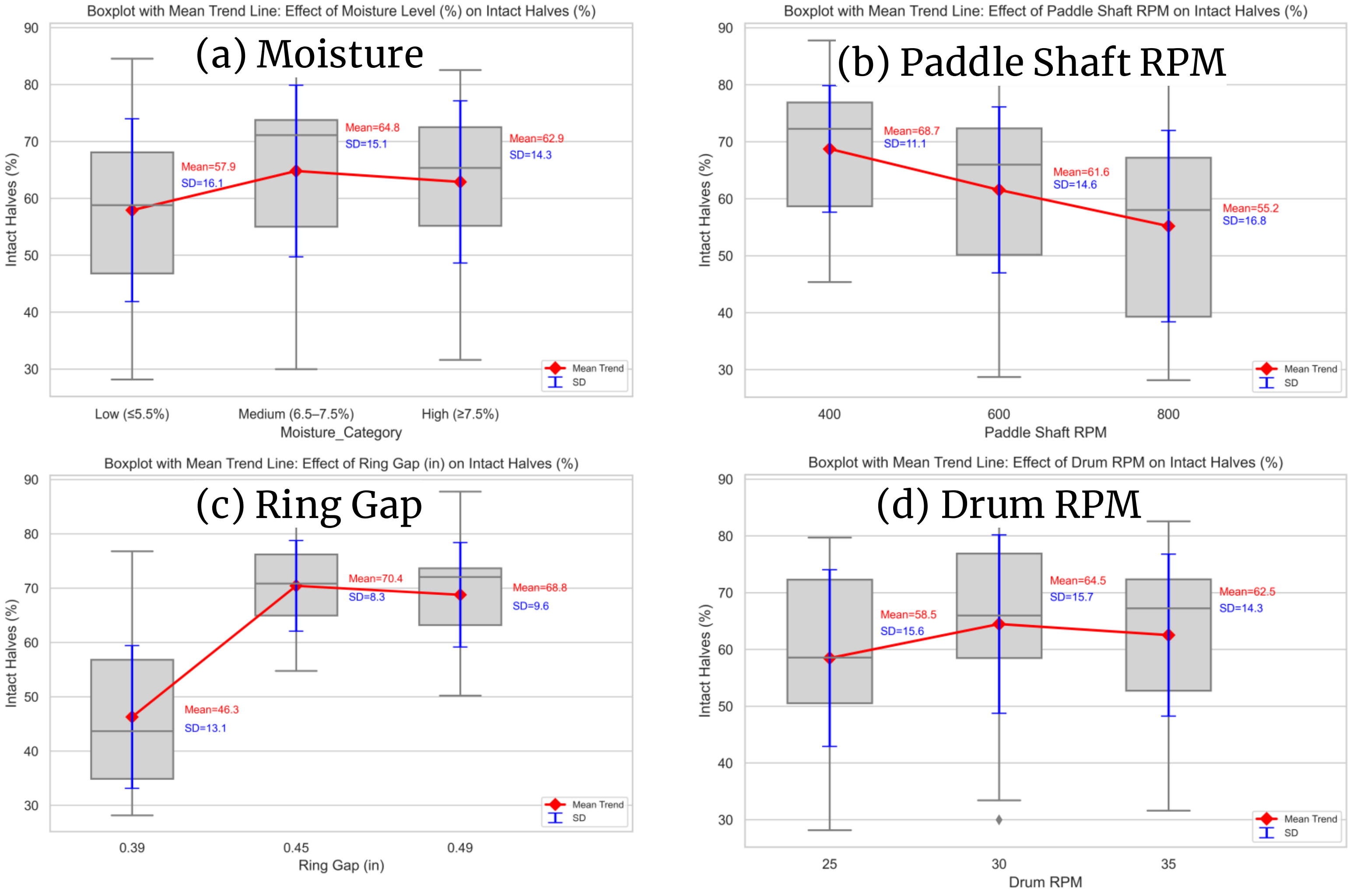
Statistical Modeling (GLM): Intact Halves (%)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ring Gap (in)	2	9478.9	4739.45	123.61	0.000
Paddle Shaft RPM	2	2380.9	1190.43	31.05	0.000
Drum RPM	2	462.2	231.12	6.03	0.005
Moisture_Category	2	592.8	296.41	7.73	0.001
Ring Gap (in)*Paddle Shaft RPM	4	985.6	246.40	6.43	0.000
Ring Gap (in)*Drum RPM	4	56.0	14.01	0.37	0.832
Ring Gap (in)*Moisture_Category	4	1335.4	333.85	8.71	0.000
Paddle Shaft RPM*Drum RPM	4	90.8	22.71	0.59	0.670
Paddle Shaft RPM*Moisture_Category	4	550.5	137.61	3.59	0.012
Drum RPM*Moisture_Category	4	93.8	23.45	0.61	0.656
Error	48	1840.4	38.34		
Lack-of-Fit	46	1655.3	35.98	0.39	0.913
Pure Error	2	185.1	92.55		
Total	80	18529.8			

- **Moisture interaction:**
- **Ring Gap * Moisture Category:** $p < 0.001$; **Paddle Shaft RPM * Moisture Category:** $p = 0.012$

Main Effects Plots: Intact Halves



- Ring Gap shows the **positive effect**, with a sharp increase from 0.39 ➔ 0.45 in.
- Paddle Shaft RPM exhibits a clear **negative trend**, with Intact Halves decreasing as RPM increases.
- Moisture displays a mild **non-linear effect**, peaking at medium levels (~6.5–7.5%).
- Drum RPM shows **minimal influence**, with only slight variation across levels.

Analysis – Discharge Throughput

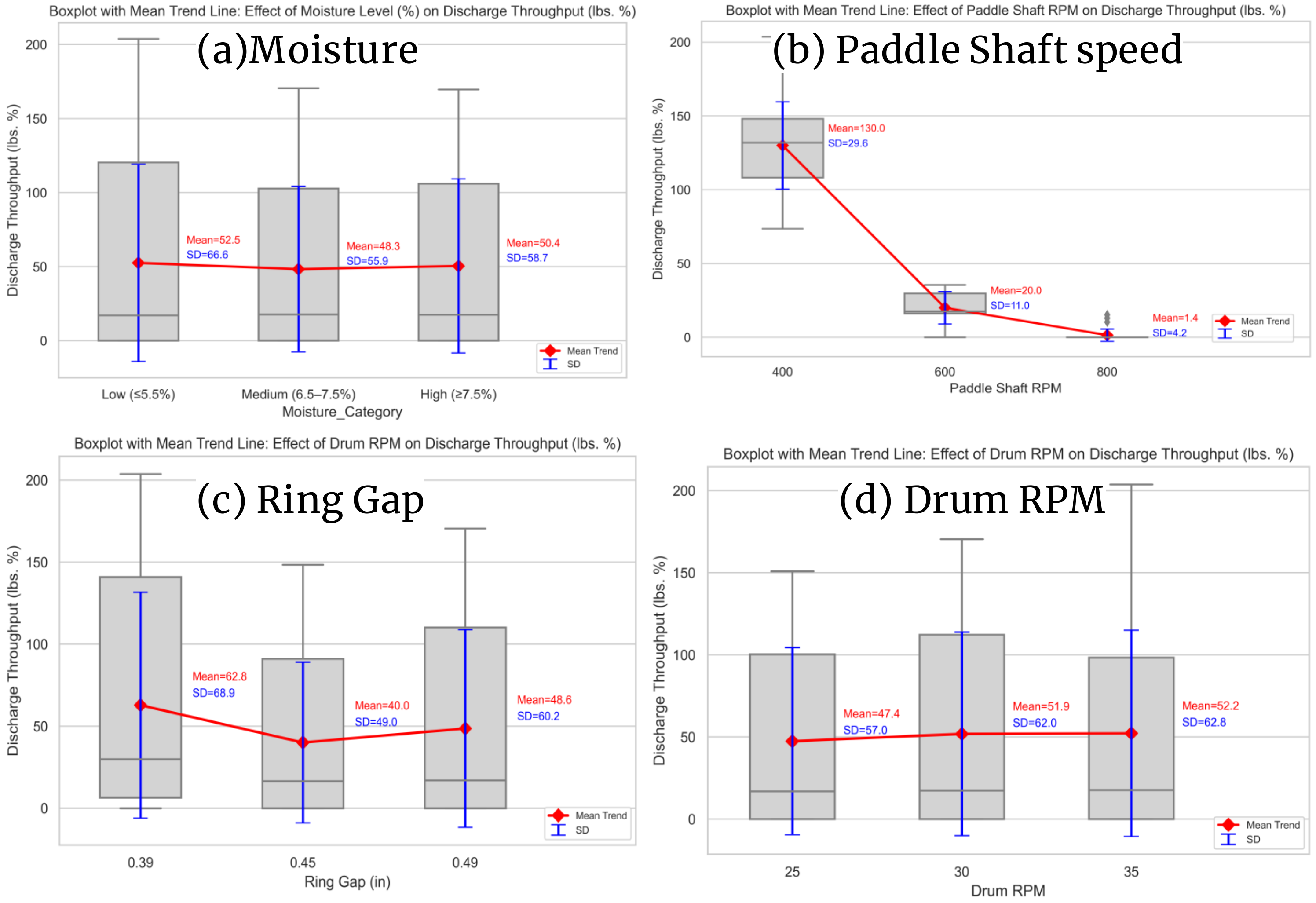
Statistical Modeling (GLM): Discharge Throughput (%)

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ring Gap (in)	2	7252	3626	21.23	0.000
Paddle Shaft RPM	2	258826	129413	757.74	0.000
Drum RPM	2	434	217	1.27	0.290
Moisture_Category	2	384	192	1.12	0.333
Ring Gap (in)*Paddle Shaft RPM	4	5572	1393	8.16	0.000
Ring Gap (in)*Drum RPM	4	1415	354	2.07	0.099
Ring Gap (in)*Moisture_Category	4	429	107	0.63	0.645
Paddle Shaft RPM*Drum RPM	4	380	95	0.56	0.695
Paddle Shaft RPM*Moisture_Category	4	1298	324	1.90	0.126
Drum RPM*Moisture_Category	4	905	226	1.33	0.274
Error	48	8198	171		
Lack-of-Fit	46	7894	172	1.13	0.581
Pure Error	2	304	152		
Total	80	287169			

- Moisture interaction:
  - **None**

Main Effects Plots: Discharge Throughput



- Paddle Shaft RPM shows a **dominant negative effect**, with Discharge Throughput dropping sharply from ~130% (400 RPM) to near zero at 800 RPM.

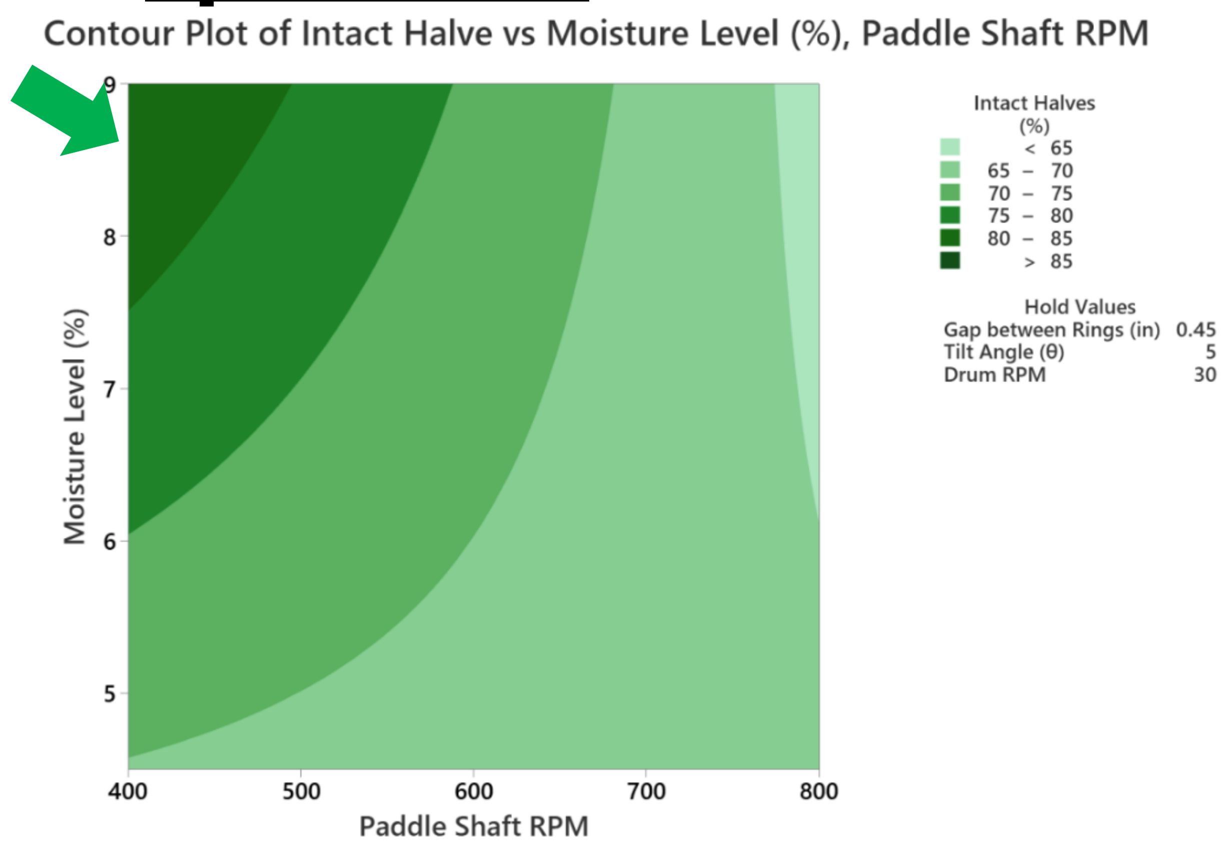
Moisture	**Drum RPM**	**Ring gap**

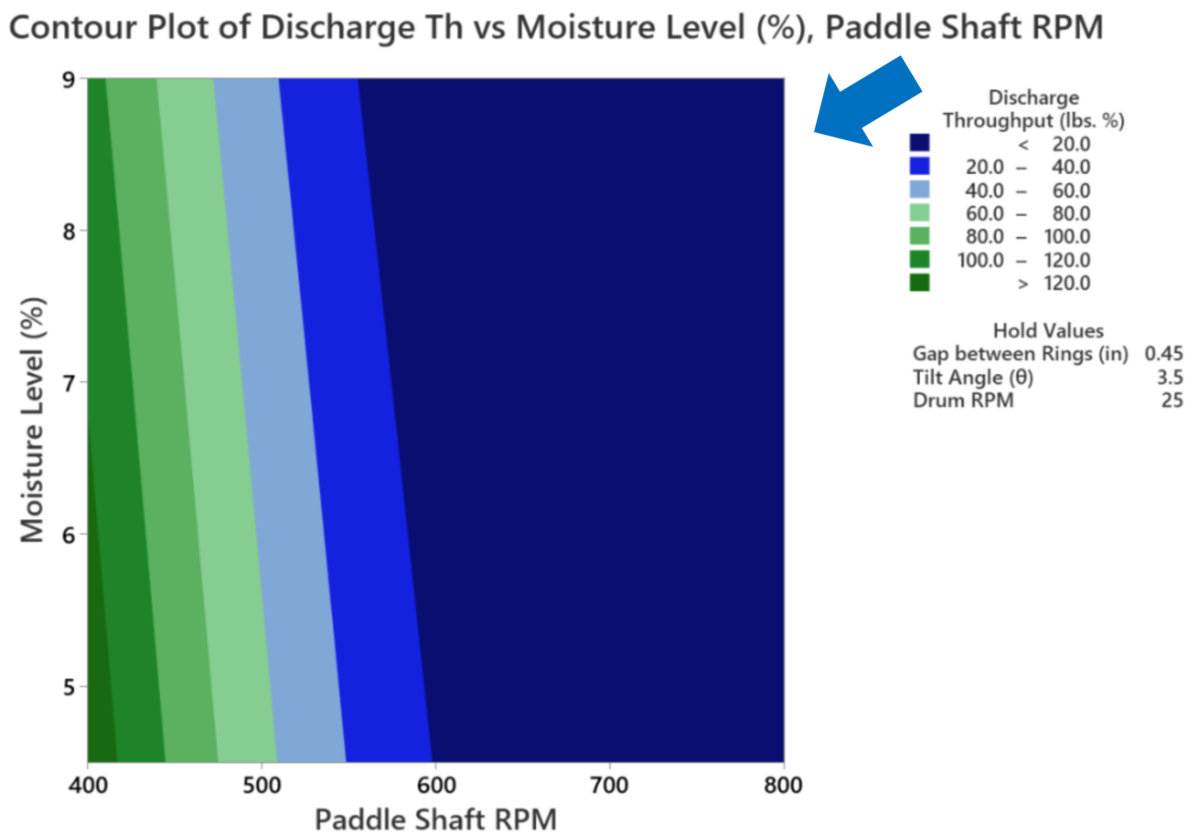
Recommendations (1)

- **Sheller parameters:**
  - **Paddle Shaft RPM: Increase**
    - **Intact Halves: Low performance**
    - **Discharge Throughput: High performance**
  - Ring Gap influence significantly on Intact Halves, high performance approximately 0.45(in).
- **Moisture interaction:**
  - Moisture interact variables has a **significant** impact on Half-Yield; has **minimal** influence on Discharge Throughput.

Optimization

Using Meyer Cracker





- Plot shows that higher Moisture Levels and lower Paddle Shaft RPM, increase Intact Halves.

- Plot shows Discharge Throughput strongly decreases as Paddle Shaft RPM increases.
- Moisture Level has minimal influence on Discharge Throughput.

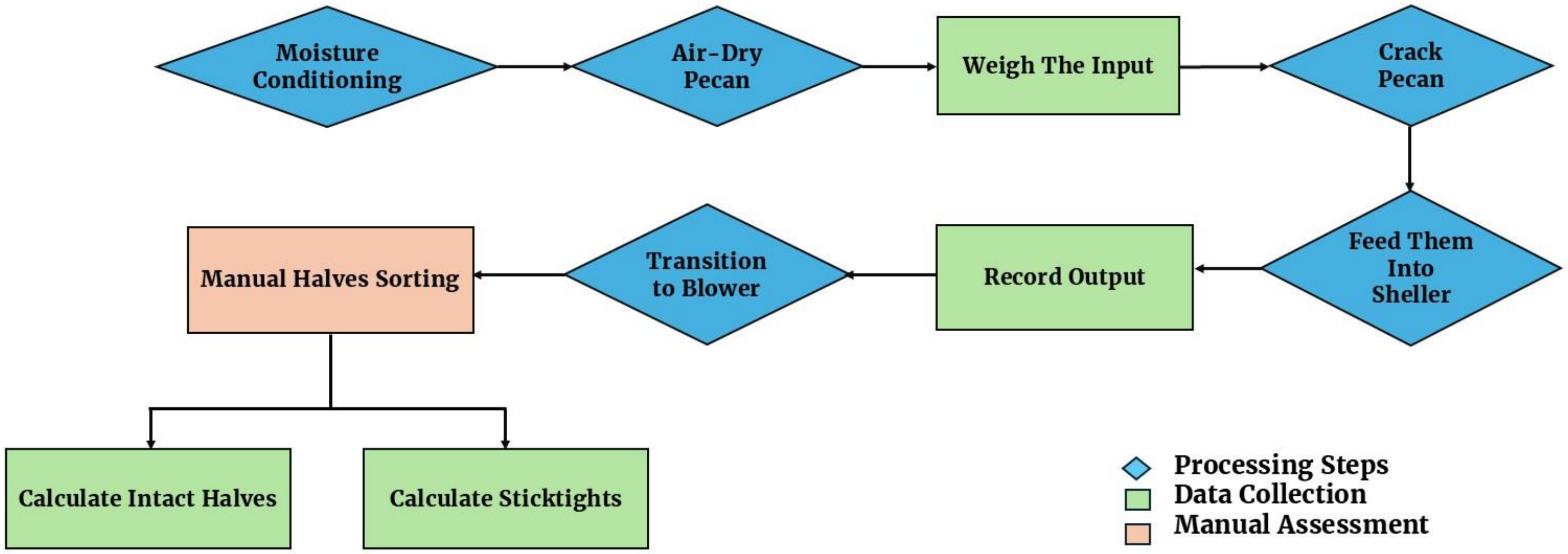
Recommendations (2) from Optimization

- **Intact Halves:**
  - As Paddle Shaft RPM ↓ and Moisture Level ↑: Intact Halves performance improves ↑
  - When the Paddle Shaft RPM is around **400 RPM** and the Moisture Level is close to **9%**, the Half-Yield rate reaches its theoretical **high performance** (>85%).

- **Discharge Throughput:**
  - If Paddle Shaft RPM ↑ (higher than 600): Discharge Throughput ↓, gradually stabilizing at a **high performance** (<20%).
  - Moisture Level has **minimal influence**. When moisture levels ↓, slightly increasing Discharge Throughput .

Sheller Pin Study

Experimental Procedure and 2025 Recap



- 2025 Workshop Recommendation:
  - **"Investigation of Sticktights"**
- 2025-2026 Pin study:
  - Make "Sticktights" as a response variable for determining the output result.

Sheller Pin Study

- **Motivation:**
  - Pin study experiment's data will help develop data- driven sheller parameters- pin configuration optimization model.
  - Optimize sheller pin configurations: enhance response variables' performance.
  - **Investigation of sticktights was requested during the 2025 workshop;** introduced and analyzed as a dependent variable for the first time.

Machine Parameters & Pin Configurations

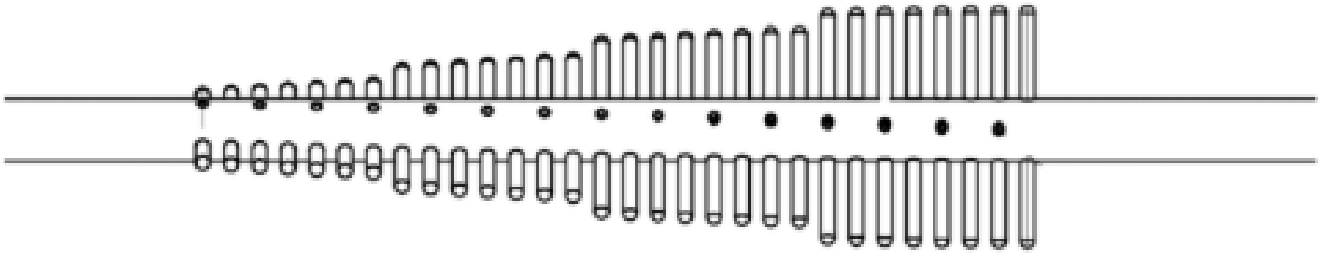
Table: Independent Variables used in Pin Study

Independent Variables
Paddle Shaft RPM (Range: 375-1100)
Ring Gap (Range: 0.39-0.51 inches)
Pin Material
Pin Length

Table: Uniform Steel and Gradient Pin Configuration

Pin Material	Pin Length
Steel	Gradient (6-8 inches pins)
Steel	Short Uniform Length (6 inch)
Polyethylene	Gradient (6-8 inches pins)
Polyethylene	Short Uniform Length (6 inch)

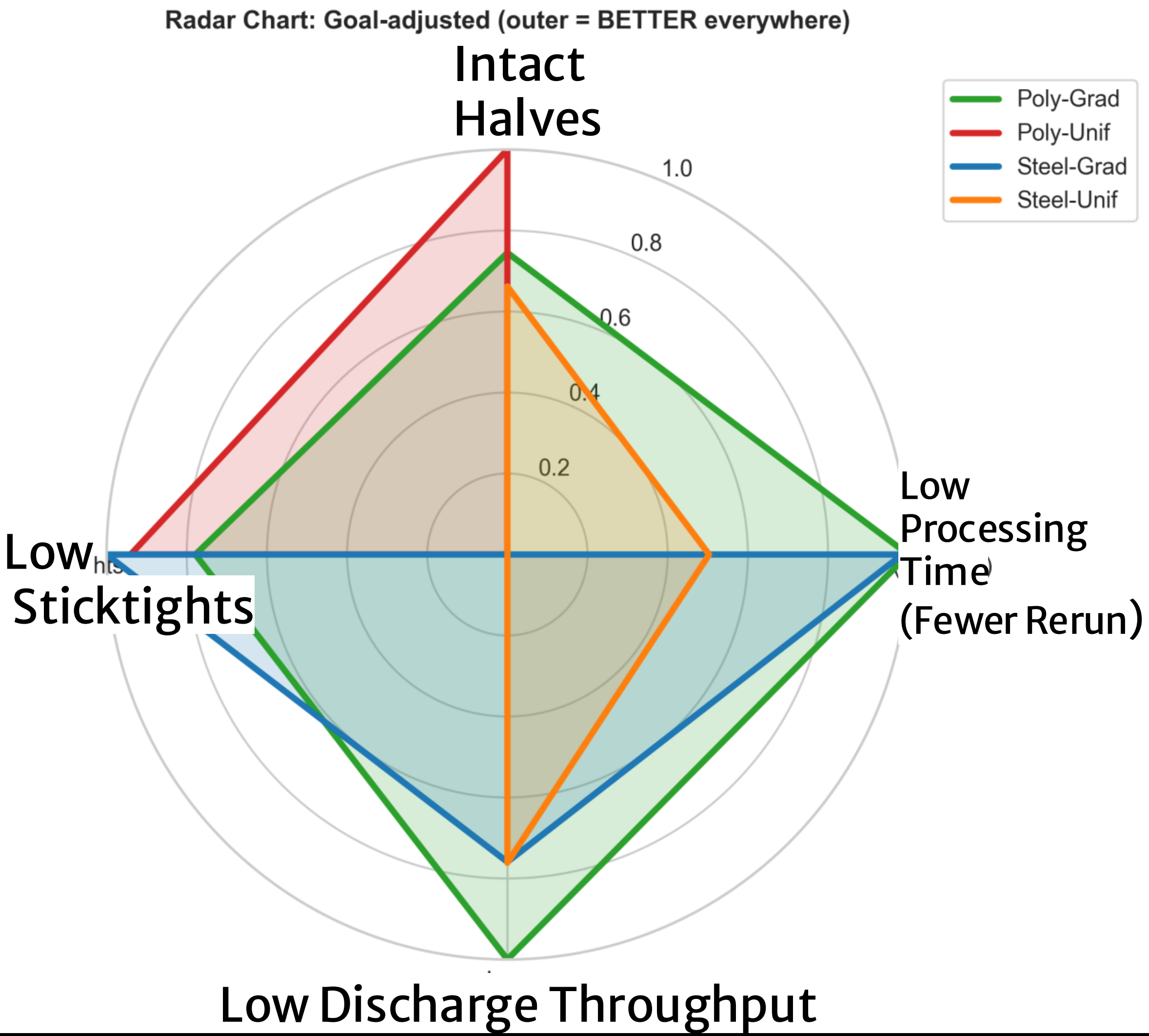
Pin Configuration of Different Materials and Lengths



Sheller Paddle Shaft with Steel pins of Gradient configuration.

(a) Gradient Steel pin configuration (regular)
(b) Gradient Polyethylene pin configuration
(c) Uniform Steel pin configuration

Result and Observation



- Using raw experimental data

- **Polyethylene – Uniform (Red)**
  - Achieves the highest intact halves percentage;

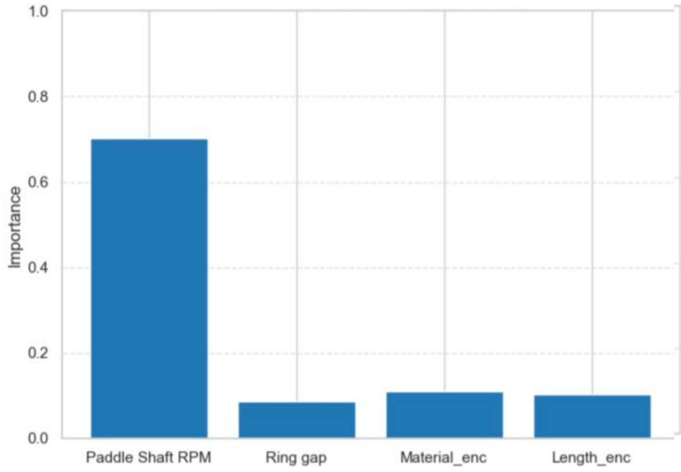
- **Polyethylene – Gradient (Green)**
  - Maintains relatively high intact halves while reducing throughput percentage ;

- **Steel – Uniform (Orange)**
  - Highest sticktight percentages with moderate Processing Times;

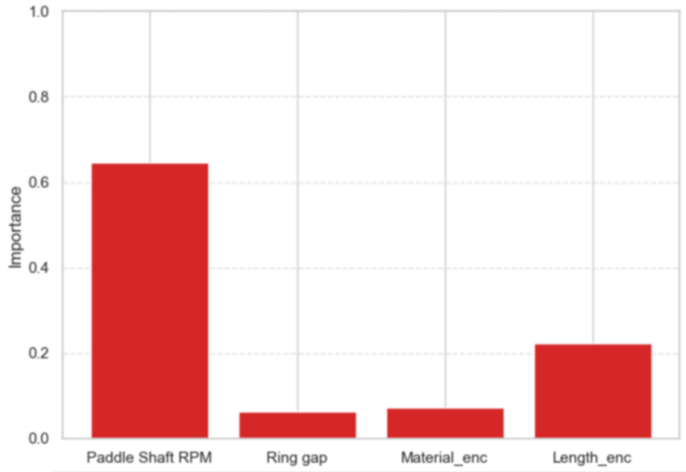
- **Steel – Gradient (Blue)**
  - Lowest Sticktight occurrence;
  - Lowest Intact Halve percentage.

Feature Importance of Independent Variables

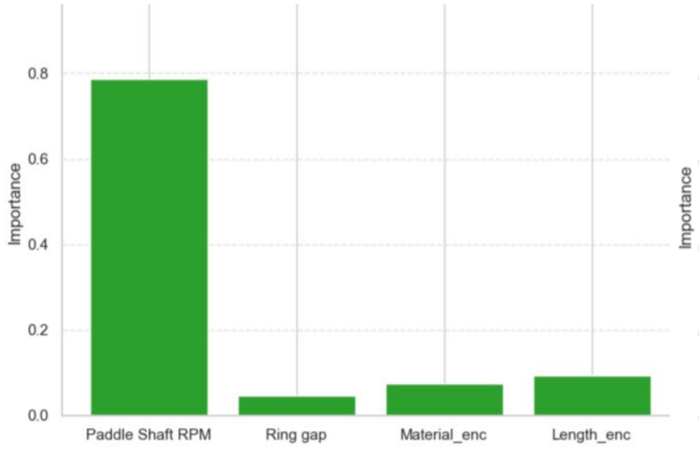
Feature Importance for Intact Halves



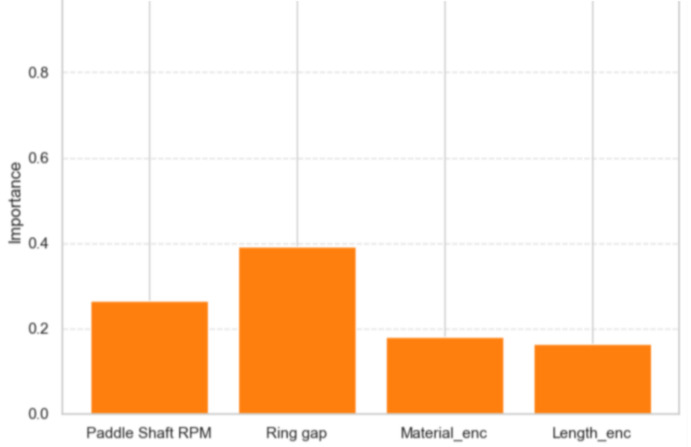
Feature Importance for Processing Time



Feature Importance for Discharge Throughputs



Feature Importance for Sticktights



Paddle Shaft RPM is the most influential parameter for **Intact Halves**, **Discharge Throughput**, **and Processing Time**, making it the key driver for overall shelling performance.

Ring Gap has the greatest impact on **Sticktights**.

Response Optimization: Intact Halves (%)

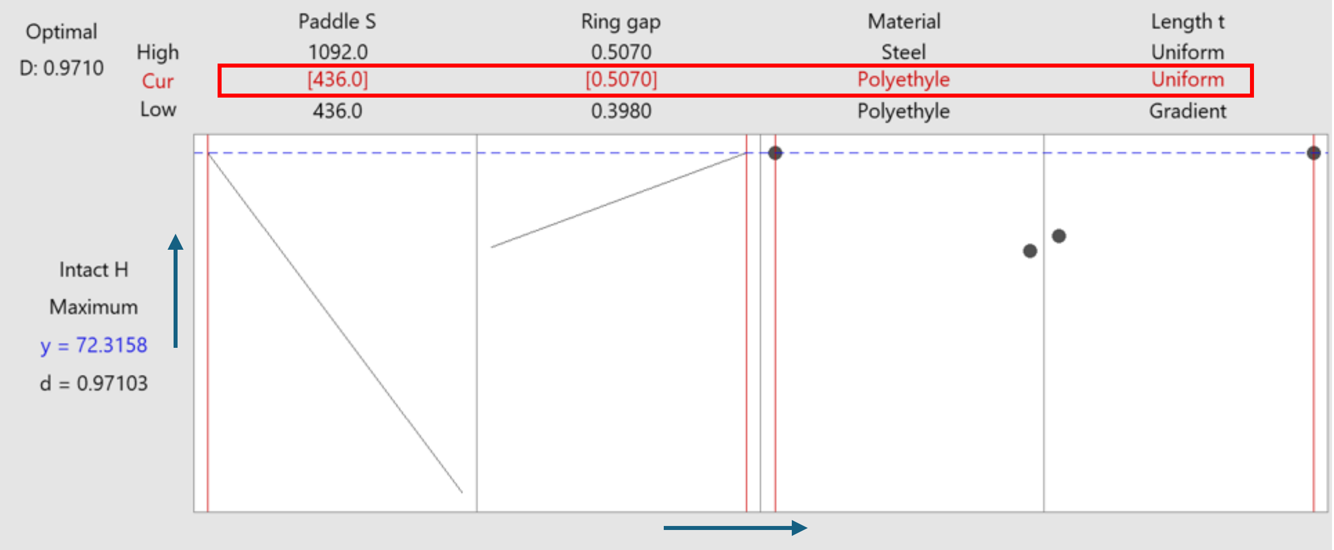
Parameters

Response	Goal	Lower	Target	Upper	Weight	Importance
Intact Halves (%)	Maximum	35.2257	73.4225		1	1

Multiple Response Prediction

Variable	Setting
Paddle Shaft RPM	436
Ring gap	0.507
Material	Polyethylene
Length type	Uniform

Response	Fit	SE Fit	95% CI	95% PI
Intact Halves (%)	72.32	1.77	(68.72, 75.91)	(63.27, 81.36)



Multi-response desirability profile for the optimization of Intact Halves.

Response Optimization:
Discharge Throughput (%), Sticktights (%), Intact Halves (%)

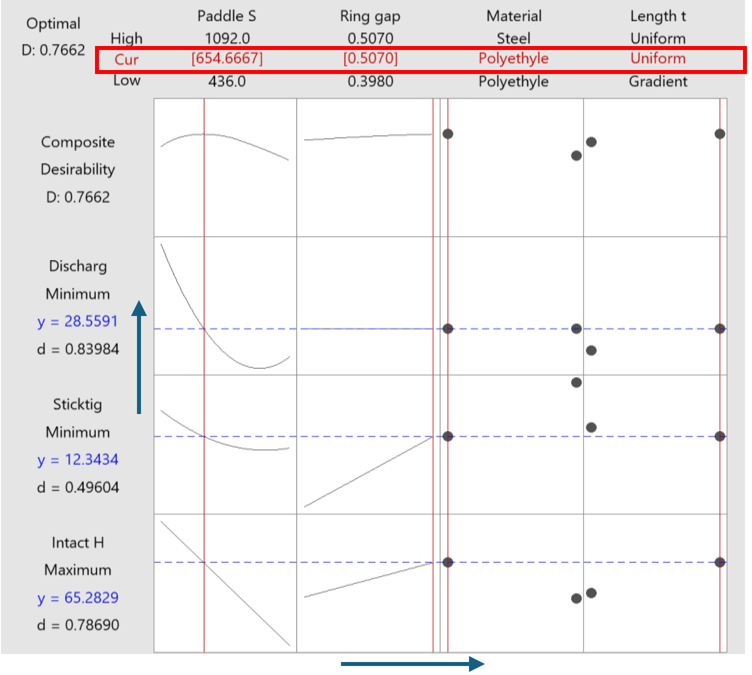
Parameters

Response	Goal	Lower	Target	Upper	Weight	Importance
Discharge Throughput (%)	Minimum		0.0100	178.261	1	3
Sticktights (%)	Minimum		1.3504	23.164	1	1
Intact Halves (%)	Maximum	35.2257	73.4225		1	6

Multiple Response Prediction

Variable	Setting
Paddle Shaft RPM	654.667
Ring gap	0.507
Material	Polyethylene
Length type	Uniform

Response	Fit	SE Fit	95% CI
Discharge Throughput (%)	28.56	6.31	(15.75, 41.37)
Sticktights (%)	12.34	1.01	(10.28, 14.40)
Intact Halves (%)	65.28	1.55	(62.14, 68.42)



Multi-response desirability profile for simultaneous optimization of Discharge Throughput, Sticktights, and Intact Halves.

- Optimization **did not** include Processing Time since Discharge Throughput and Processing Time are highly correlated.

Recommendations

- **Polyethylene–Uniform: Top pin configuration** based on the **optimized data**. Strong performance for Half-Yield and Sticktights.

Pin Configuration	Intact Halves	Sticktights	Processing Time	Discharge Throughput	Overall Performance
Polyethylene–Uniform	Highest performance	Highest performance	Medium performance	Medium performance	Strong performance for Intact Halves & Sticktights

  - However, **optimization indicates that the overall performance** of **Polyethylene–Uniform** can be improved through appropriate **sheller settings**.

Main Focus	Paddle Shaft RPM	Ring Gap (in)	Pin Material	Pin Length
Maximizing Intact Halves	654.67	0.5070	Polyethylene	Uniform (Short)

- Overall, **Uniform (short)** configurations demonstrated significant performance and should be considered in future pin configuration studies.

Comments

- **No wear data were collected for polyethylene**, limiting assessment of its long-term durability and suitability for production use.

- Currently constructing follow-up study of these important effects:
  - **New comprehensive DOE** for pin study needs to be finalized.
  - More pin study **experimental work** needs to be conducted.

Publications

- **Paper 1: Experimental Evaluation of Sheller Machine Settings for Pecan Half Yield**
  - Submitted for publication-Fall 2026
- **Paper 2: Exploration of Moisture Effects and Sheller Process Variables for Pecan Half Yield**
  - The paper is based on the data from first experiment of this presentation.
- **Paper 3: Pin Configuration effect on Pecan half yield and sticktights**
  - The paper will be based on the 2025 Pin Study and the Proposed 2026 ME&E Pin Study.

Future Work

- **Publish Paper 2:** *Exploration of Moisture Effects and Sheller Process Variables for Pecan Half Yield* – Fall 2026
- **2026 Pin Study**
  - Continue working to finalize DoE – September 2026
  - Conduct experimental work at ME&E facility in Grand Cane, LA – Fall 2026
  - Analyze experimental work and finish manuscript for Paper 3 – Early 2027
- **Multi-Stage Experiments**
  - Continue to support experimental work on our in-house pecan processing line.

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All slides available: https://pecanresearch.uga.edu/

Thank you!

Please let us know your questions and comments!

Special Thanks to **Ayoub Heydarzade** (Graduate Research Assistant)